

STUDY ON ULTRASONIC WELDING OF ALUMINUM SHEETS

A THESIS SUBMITTED IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology in Mechanical Engineering

By

AJITESH SAHOO

111ME0340

Under the Guidance of

Prof. S.K.SAHOO



Department of Mechanical Engineering

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CERTIFICATE

This is to certify that thesis entitled, “STUDY ON ULTRASONIC WELDING OF ALUMINUM SHEETS” submitted by Mr. Ajitesh Sahoo in partial fulfillment of the requirements for the award of *Bachelor of Technology* Degree in Mechanical Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter included in this thesis has not been submitted to any other university/ institute for award of any Degree or Diploma.

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DATE-

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ABSTRACT

Ultrasonic welding is used to weld thin sheet metals of similar or dissimilar couples of non-ferrous alloys like copper, aluminum and magnesium without addition of filler material resulting in high quality weld; it can count on a low energy consumption and on a joining mechanism based on a solid state plastic deformation which creates a very homogeneous metallic-structure between the base materials, free from pores & characterized by refined grains and confined inclusions' Ultrasonic metal-welding can join also painted or covered sheet metals. Thin sheets of aluminium have been joined by means of Ultrasonic spot Welding. Results are particularly effective in order to evaluate the relevance of various phenomena influencing the lap joint technique obtained on thin aluminium by the application of Ultrasonic Metal Spot Welding (USMSW). The Present study considers the experiments carried out on the aluminum sheets joints at room temperature. The aim is to evaluate the factors influencing the lap joining technique, allowing a deep understanding of the phenomena and the possibility to keep them under control. In this project, the ultrasonic welding of aluminium sheets are carried out under different amplitude, weld pressure & weld time and their effect on tensile strength of ultrasonic welding is analyzed.

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CHAPTER-1
INTRODUCTION

1. INTRODUCTION

1.1 Ultrasonic Welding

Ultrasonic metal welding (USMW) was invented over 50 years ago and has now been in use in industry for many years. USMW is a process in which two metals are joined by the application of ultrasonic vibrations, under moderate pressure, in which the vibrations are applied parallel to the interface between the parts. The high frequency relative motion between the parts forms a solid-state weld through progressive shearing and plastic deformation between surface asperities that disperses oxides and contaminants and brings an increasing area of pure metal contact between, and bonding of, the adjacent surfaces.

This study explores joining various thicknesses of aluminum alloy 5754 with ultrasonic energy, in order to find the optimum parameters and conditions of this technology. Its final application will be the production of the aluminum automobile frames.

Two major types of ultrasonic welding machines are

1. Ultrasonic plastic welding machine (USPW)
2. Ultrasonic metal welding machine (USMW)

1.2 Ultrasonic Metal Welding

Ultrasonic metal welding (USMW) is used in many fields like automotive, shipbuilding, architectural industries and brazing in electronic components manufacture. Ultrasonic can be used to weld different metals together, without solder and flux or special preparation. The process is different from plastic welding in that the two components are vibrated parallel to the interface as shown in fig.1. Ultrasonic metal welding consists of fundamental parts.

1. The electrical part
2. The electromechanical transducer
3. The mechanical part

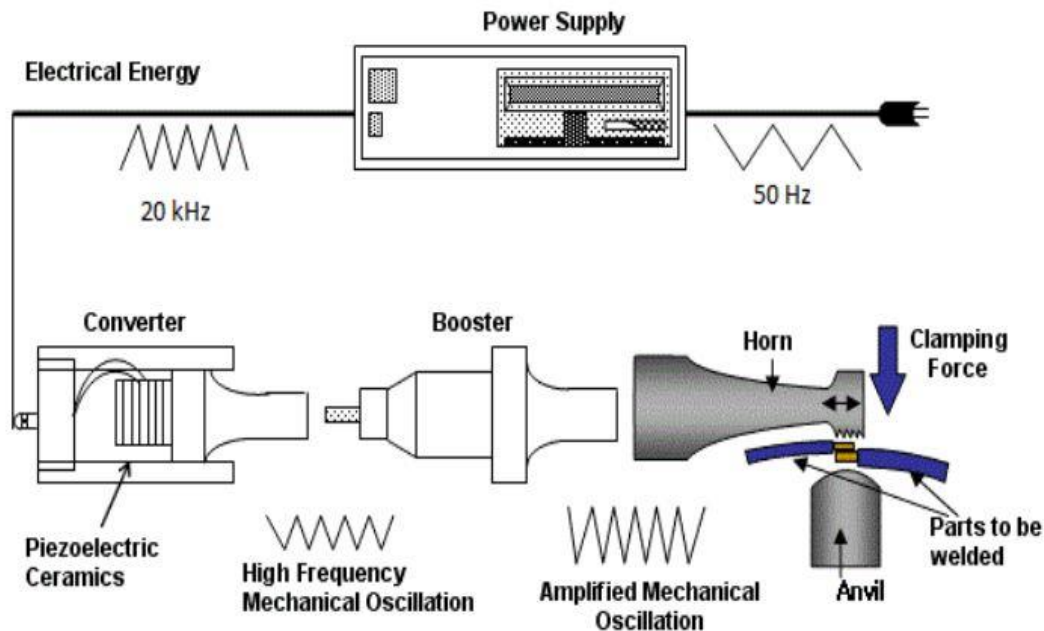


Fig1. Illustration of ultrasonic metal welding system [1]

1.3 Principle of USMW set up for spot welding

It is to be noted that ultrasonic metal welding is quite distinct from an allied ultrasonic joining process, that of plastic welding. Whereas the ultrasonic vibrations in metal welding are parallel to the part surfaces, they are at perpendicular to the surfaces in plastic welding. And, whereas the nature of the bond in metal welding is solid state – that is, without melting and fusion of the adjacent metals, the plastic welding process depends on melting and coalescence of adjacent plastic material. Nevertheless, it frequently occurs that many components of the ultrasonic equipment, such as transducers, power supplies and horns, may be similar, if not identical, between the two processes. Even though USMW has been known for a number of years, a complete understanding of the fundamental mechanism of the process is far from complete.

This lack of full understanding is particularly pronounced as it relates to the basic mechanics of the weld, and the relation of the weld mechanics to the overall dynamics of the ultrasonic welding system. In the case of weld mechanics, the lack of knowledge of the shear and normal forces, and plastic deformation in the weld zone are to be especially noted. While 3 extensive studies of USMW have been made, most have been focused on the resulting weld metallurgy, or on the weldability of various metal combinations. Efforts have also gone into the problem of finding the equivalent electrical circuit representation for the ultrasonic welding system. Substantial efforts have also gone into the ultrasonic micro joining process, widely used in microelectronics for linking microchips to circuits.

Despite an extensive body of prior work, users of USMW face significant challenges in extending the process to heavy duty welding of structural components that can find use in automotive and aerospace structures. Specifically, this relates to joining of 5XXX and 6XXX series aluminums, widely used in the automobile industry, and to 2XXX, 6XXX and 7XXX aluminums used in the aerospace industries. These challenges arise in part because of the thickness and in part because of elastic vibrations of the parts. These problems do not emerge while welding metal wires and foils.

From a practical applications standpoint, two key areas have emerged that impede progress. The first problem is that of varying weld quality when successive welds are made with what appear to be identical system welding parameters. The second problem is that of “sticking” between the parts being welded and the weld tooling. This sticking which is, in fact, a welding of the parts to the tooling with this welding being in addition to the welding between the parts, or sometimes being

instead of welding between the parts), usually is found to occur, when it does occur, between the top part and the vibrating tool on the welding sonotrode. Without a solution to these problems it will be difficult to extend USMW to high production, larger scale welding of structures, despite other potential advantages of the process.

It is the purpose of this dissertation to address these two key issues of USMW. The basis of the approach will be to understand the underlying mechanics, involving the welding forces occurring at the part interfaces (i.e. at the part-part and part-tool interfaces), and within the parts, during welding, and from this understanding, to better explain the root causes of “sticking” and weld variability.

USMW systems employ means of controlling input process parameters, and the in-process weld cycle that are intended to reduce weld variability. Thus, the most common practice to control the process is by measuring and controlling the electrical input to the transducer. In certain systems, this is sufficient to control the velocity of the sonotrode, but does not provide information on the forces at the weld interface and their effect on weld quality. Overall systems representations have been developed, representing the ultrasonic welding system as an equivalent electrical network. While these can give an electrical input impedance of the transducer, their relationship to the mechanical impedance at the weld is separated by several “transfer functions” involving the transducer, acoustic transmission components and weld tooling, from the weld itself. Thus, it has been found that knowledge purely of electrical input parameters to a welding system do not provide the ability to eliminate the key issues of variability and tool sticking.

1.4 PRINCIPLES OF ULTRASONIC METAL WELDING

The application of ultrasound to metal joining, for improving grain refinement of fusion welds, and for brazing and soldering, dates back over 60 years. The first steps to the discovery of ultrasonic metal welding (USMW) “as we now know it” occurred in the late 1940’s when, in research at the Aeroprojects Company of West Chester, Pennsylvania (the forerunner of the current Sonobond Corporation), ultrasonic vibrations were applied to conventional resistance welding equipment, with the objective of decreasing surface resistance in spot welding of aluminums [2]. In the course of this work, it was discovered that ultrasound alone was capable of producing a bonding of the metals. Initial equipment used a longitudinal mode of vibration to the work pieces, similar to that used today for ultrasonic plastic welding. Further study showed that lateral vibration components of the sonotrode were in fact responsible for the traces of bonding observed in the parts. Added development was aimed at enhancing this transverse vibration, and led, by the mid-1950, to both the wedge-reed and lateral drive configurations now in use. Extensive research efforts spread to other laboratories in the United States by the late 1950’s, and soon after that, research groups throughout the world, but especially in the (former) Soviet Union, initiated efforts.

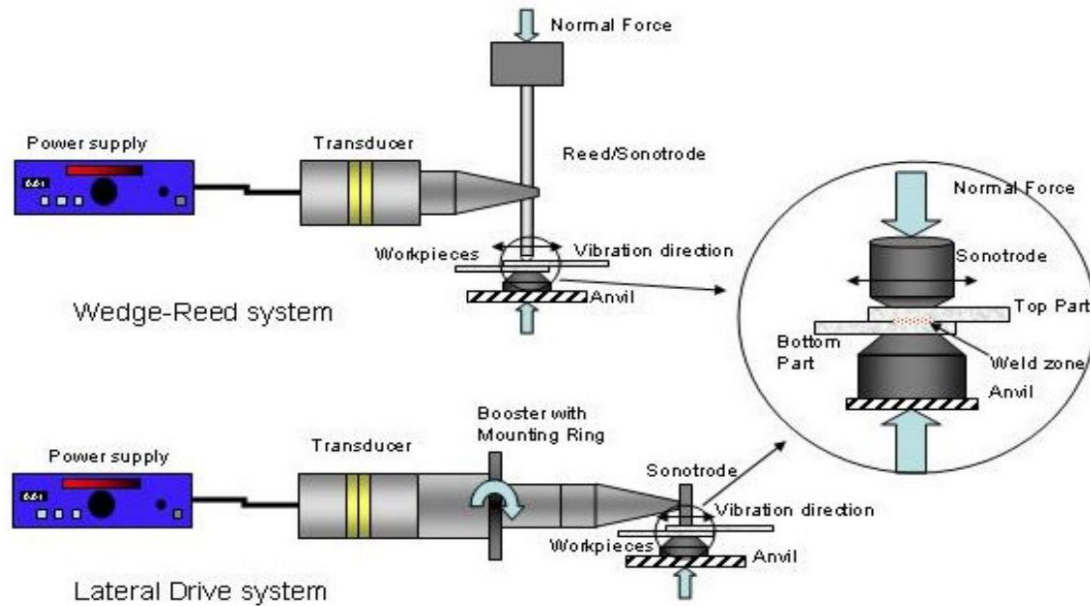


Fig2. Wedge-Reed and Lateral Drive ultrasonic welding systems [3]

In this Figure the two most widely used systems for ultrasonic spot welding, the wedge-reed and the lateral-drive system are shown. Thus for the wedge-reed system electrical power is converted into mechanical longitudinal vibrations by the transducer. This longitudinal vibration is amplified and transmitted into the reed by a metal wedge, brazed to the reed forcing it into transverse vibrations. The normal force is applied by a pneumatic cylinder onto the mass at the top of the reed. It is seen that the ultrasonic vibration is transmitted into the parts being welded via the transverse vibration occurring at the end of the reed. For the lateral-drive welder, the system components are the transducer, a booster with mounting ring and a horn with sonotrode (sometimes known as the 'stack'). Booster and horn amplify the longitudinal vibrations generated by the transducer. The booster also serves as mount for the entire stack, at which either a torque or a linear downward force is applied, so that the sonotrode is pressed onto the parts. The sonotrode is mounted perpendicular to the vibration direction of the horn and therefore vibrating transversely. The ultrasonic energy is transmitted into the work pieces via the transverse vibration occurring at the tip of the welding horn. In both systems, the vibrations at the sonotrode are transverse, and occur in a linear, cyclic manner. Both systems are designed to be in resonance at their specific operating frequency - deviation from this frequency by a few hundred Hertz will eliminate the vibration amplification thereby reduce the amplitude at the sonotrode significantly. The amplitude of vibration at the work pieces varies by system, by tool design and by power settings for a given application. Nevertheless, they typically will fall into the range of 10 – 100 microns, peak-to-peak. Likewise, the static forces applied to the weld will also vary by system and application, but will typically fall in the range of a few hundred Newton to several kilo Newton. These static forces alone are well below those necessary to impart any noticeable plastic deformation to the work pieces.

The details of the welding action at the work pieces are shown in the encircled area of figure. Thus, in the wedge-reed and lateral-drive systems shown, there is little difference of the welding action at the work pieces. However, what has been shown are the cases of rigid anvils, for both the wedge-reed and lateral-drive systems. In the most widely used versions of the wedge-reed system, the anvil itself is also a vibrating element, flexing in a similar manner to the reed. In particular, the anvil is designed to be “contra-resonant”, vibrating in a manner to achieve an increased relative motion at the work pieces.

There are other types of USMW systems that find uses for special welding applications. Thus, an ultrasonic seam welder utilizes a rotating disc as the sonotrode. With this method the vibrations can be transmitted continuously to the work as it rolls through the sonotrode-anvil jaw. Welders of that type are capable of producing seam welds in metals of foil thickness. Ultrasonic torsion welders introduce the vibrations not in a linear but a circular mode, making them suitable to weld rotational symmetric welds. The main current application of this type of welder is to seal metal packages. While it is believed that the principles of ultrasonic metal spot welding that are developed in this dissertation will find application to enhancing these related processes, these modes of ultrasonic metal welding will not be examined here.

In addition, experimental welders have been developed that operate in other vibration modes systems that are or have been studied are welders that operate in a complex vibrating mode, apply the vibrations from the top and the bottom and welders that are capable of butt welding. Welders using complex vibration modes are in principle wedge reed welders, where the wedges and transducers are attached perpendicular to each other on the same reed. These two wedges then have different operating frequencies so that a complex vibration pattern (Lissajous pattern) is generated at the sonotrode parallel to the weld interface. A second scheme for generating a complex vibration pattern is to utilize a slotted booster and horn in a lateral-drive system. The slotted booster vibrates in a combined longitudinal and torsional mode, causing a complex welding pattern. To apply the vibration from both sides, a second welding system is taken as an anvil, so that top and bottom part are excited simultaneously to opposing vibrations. Butt welding is performed with a high power system using an array of multiple transducers that drive a horn with a clamp at the end. The part to be welded is then clamped to the horn and vibrating transversely. Simplified this system is lateral drive system, welding the sonotrode to the work pieces, and then detaching the sonotrode from the horn. Commercially these types of welders are of low relevance. Welders with a very high power output can spot weld sheet metal up to 3mm thickness, when the vibrations are applied only from one side. With the ultrasonic butt welding system up to 10mm thick Aluminum can be successfully welded.

The most important parameters that have to be considered in USMW can be separated into system and materials parameters. The main system parameters are:

- Welding time
- Amplitude of vibration
- Static pressure on the parts (Clamping Force)
- Electrical Power
- Frequency

The material parameters, including work piece features, include:

- Sample cleanliness (Oxides or Contaminants)
- Crystal structure
- Hardness
- Dimensions

As mentioned it can be assumed that the formation of the bond can have different causes, depending on the scale of the application and the properties of the material. The joining process should be clearly separated into small and large scale applications. The separation is of course not that clear and simple, but in an application in which an amplitude in excess of 10 μm and a power level exceeding a few hundred watts it is safe to talk of a large scale application. For these power levels and amplitudes only welding systems that operate at 20 kHz or lower can be used. In large-scale applications typically sheet metal is welded where the bending stiffness of the sheets to be welded reaches noticeable levels. Small-scale applications use higher frequencies (>20 kHz up to several hundred kHz) and smaller amplitude (<10 μm). Small-scale applications are commonly wire bonding and foil welding. A key attractive feature of USMW is that it is a solid-state bonding process, so that issues involving melting, solidification of the base metals, with resulting impact on material properties, are not present. This becomes clear when the ultrasonic process is compared to resistance spot welding (RSW) of aluminum [4]. The mechanical and chemical properties are generally not changed by the USMW process. In resistance welding the weld spot melts and re-solidifies and the adjacent areas to the weld are strongly influenced by the high temperatures during welding. This means if a heat treated aluminum alloy is resistance spot welded it loses its properties gained by heat treating. The resulting resistance spot weld is therefore weaker than a comparable US spot weld. In addition, the energy consumption during USMW is considerably less than in RSW. This eliminates the need for water cooling and heavy transformers. Other significant advantages of USMW are that welding of two different materials and thickness is possible and that the external deformation of the parts can be as low as 5%

1.5 Aluminum

Researchers state that, “aluminum comprises 8% of the earth’s crust and is, therefore the most abundant structural metal” [5]. Its production is higher than that of copper, and second compared to iron. Initially its unit price was very high which steadily decreased with new smelting technologies. Today the price of aluminum is lower than the price of copper. Because of its electrical properties it is competing with copper in the electric and construction industry. Although the electrical conductivity of aluminum is slightly lower than that of copper, it is preferred over copper in power cables because of its lighter weight. Aluminum used in the industry can be anodized to produce a protective oxide film, which can be dyed to give a colorful appearance. The anodizing process uses a bath of dilute sulfuric acid as an electrolyte and charging the piece electrically. The piece that is being anodized is the anode –the positive pole -- and the electrolyte becomes the negative pole –the cathode. The electrical charge and the mild acid oxidize the aluminum surface, leading to microscopic crystals of aluminum oxide, which is very hard, but very porous. This porosity is responsible for absorbing and holding the colors of the dye. After the anodized part is removed from the bath it is dipped into a container of concentrated color (dye) for several minutes. After dying, the part is immersed in clean, boiling water for several minutes to close the pores and seal the dye by hydrating the crystalline layer and swelling the oxide.

1.5.1 Aluminum alloys

When the electrolytic reduction of alumina (Al_2O_3) (produced from bauxite) was developed by Charles Hall in Ohio and Paul Heroult in France in 1886, the first “aluminum internal-combustion-engine-powered vehicles” appeared, and aluminum started to play an important role in the automotive industry. Since then, alloys of aluminum have been developed, improving its properties and making it extremely popular in different industries. These alloys are light weight, strong, electrically and thermally conductive and have good corrosion resistance. Aluminum alloys can be divided into two major categories: casting and wrought. Cast is aluminum produced in a foundry. Aluminum ingots are melted in furnaces and the molten aluminum is poured into molds. Wrought is the aluminum formed of sheet, strip or bar stock that is “hand-worked”. The aluminum is heated in a forge and hammered to shape. For wrought alloys a four digit system is used to produce a list of wrought composition families as follows

- 1xxx Controlled unalloyed (pure) composition. Used primarily in the electrical and chemical industries.
- 2xxx Alloys in which copper is the principal alloying element, though other elements, notably magnesium, may be specified. They are widely used in aircraft.
- 3xxx Alloys in which manganese is the principal alloying element. Used as a general purpose alloy for architectural applications and various products.

- 4xxx Alloys in which silicon is the principal alloying element. Used in welding rods and brazing sheet.
- 5xxx Alloys in which magnesium is the principal alloying element. Used in boat hulls and other products exposed to marine environments.
- 6xxx Alloys in which magnesium and silicon are principal alloying elements. Commonly used for architectural extrusions.
- 7xxx Alloys in which zinc is the principal alloying element, but other elements such as copper, magnesium, chromium and zirconium may be specified. Used in aircraft structural components and other high-strength applications.
- 8xxx Alloys including tin and some lithium compositions, characterizing miscellaneous compositions.

Casting compositions are described by a three-digit system followed by a decimal value. The term “heat treatable” for the aluminium alloys, both wrought and cast, is used for specific operations employed to increase strength and hardness by precipitation hardening. Thus the term heat treatable distinguishes these alloys from those alloys in which no significant strength improvement can be achieved by heating and cooling

1.5.2 Cold working

The non-heat treatable alloys depend primarily on cold work to increase mechanical properties. Cold work occurs as a consequence of plastic deformation at low to moderate temperatures. Such deformation increases the concentration of dislocations. Energy is added to the material, being applied fast enough and in large enough magnitude to not only move existing dislocations, but also to produce a high number of new dislocations. A metal filled with dislocations will hinder the movement of any one large dislocation. Thus plastic deformation cannot occur at normal stress levels where work hardening is been completed. That is to say, the small dislocations act as crack inhibitors which stop large fracture defects from growing. A much higher force is required in order to overcome the strain-field interactions and break the cold worked material. Therefore, the yield strength is increased.

1.5.3 Heat treating

Annealing is a process that produces equilibrium conditions by heating and maintaining at a certain temperature and cooling very slowly to allow the internal stresses grain growth. In the recovery phase the metal is softened by removal of the crystal defects and internal stresses. Second phase, re-crystallization consists of new grains nucleation and grow, replacing those crystals that have internal stresses. If annealing is allowed to continue beyond the re-crystallization completion, the grains start to grow, leading to a coarsen microstructure (less than satisfactory mechanical properties). Annealing is applied to both grades of aluminium to promote softening. Complete and partial annealing heat treatments are the only ones used for the non-heat treatable alloys.

The exception is the 5000 series alloys which are sometimes given low temperature stabilization treatment. Annealing is carried out in the range 300-410°C depending on the alloy. Heating times vary from 0.5 to 3 hours, depending on the size of the load and the alloy type. Rate of cooling after annealing is not critical. Solution heat treatment is applicable to the heat treatable alloys and involves a heat treatment process by which the alloying constituents are taken into a solution and retained by rapid quenching. Subsequent heat treatment at lower temperatures, such as ageing or natural ageing at room temperature, allows for a controlled precipitation of the constituents, thus achieving increased hardness and strength. Time at temperature for solution treatment depends on the type of alloy and the furnace load. Sufficient time must be allowed to take the alloys into solution if optimum properties are to be obtained. The speed of quenching is important. Generally, rapid formation of precipitates of constituents begins at around 450°C for most alloys and it must not fall below this temperature prior to quenching [6]. The usual quenching medium is water at room temperature, although in some circumstances “slow quenching is desirable, as this improves the resistance to stress corrosion cracking of certain copper-free Al-Zn-Mg alloys” [6]. Parts with complex shapes may be quenched at slower quenching rates to decrease distortion. After solution treatment and quenching, hardening is achieved either at room temperature (natural ageing) or with a precipitation heat treatment (artificial ageing). In some alloys sufficient precipitation occurs in a few days at room temperature to yield stable products with the desired properties. However, in some cases these alloys are precipitation heat treated to provide increased strength and hardness in wrought and cast alloys. Other alloys with slow precipitation reactions at room temperature are heat treated at high temperatures before being used. Where natural ageing is carried out, the time may vary from around 5 days for the 2xxx series alloys to around 30 days for other alloys. The 6xxx and 7xxx series alloys are considerably less stable at room temperature and continue to mechanical properties for many years. With some alloys, natural ageing may be suppressed or delayed for several days by refrigeration at -18°C or lower. The artificial ageing or precipitation heat treatments are low temperature, long time processes. Temperatures range from 115-200°C and times from 5-48 hours. Accurate temperature control and variation temperatures are critical to the process and generally temperatures should be held to a range of $\pm 7^\circ\text{C}$. In order to prevent a significant loss of mechanical properties, the over aging must be avoided. Over aging, consisting of longer times and higher temperatures, leads to larger particles and precipitates. The objective is to select the cycle that produces the optimum precipitate size and distribution pattern. Unfortunately, one cycle may achieve a maximum in one property, such as strength, but it may not provide optimum values for the other properties such as yield strength and corrosion resistance. Consequently, the cycles used represent compromises that provide the best combination of properties.

CHAPTER - 2
LITERATURE REVIEW

2. LITERATURE REVIEW

2.1 Theory of the microscopic bonding mechanism without fusion

Ultrasonic welding is a special form of welding in the solid state. As with other forms of solid state welding, joint formation takes place in three stages. Wodara [7] has summarized this theory and will be reviewed in the following'

In the first stage, the surfaces that will be welded are drawn together. This will cause the surfaces to align themselves, due to the normal stress acting on the surfaces. In the second stage, the atoms of the joining surfaces are activated (i.e. dislocations are generated) and, at close approach, chemical (electron) exchange effects take place (namely a metallic bond is formed). In the third stage, which leads to the formation of a strong joint, exchange effects occur between the metallic substances, both in the weld and the neighboring areas. The exchange effects are diffusion of atoms on a microscopic scale, due to the deformation of the unit cells and the very high dislocation density. This theory is a general approach to explain joint formation in the solid state not limited to USMW. The three stages during the bond formation take place within very short time intervals and are therefore hard to separate. The three stages of bond formation are described in more detail in the following.

In the first stage, as soon as the static pressure and the tangential force of the sonotrode are applied, asperities wear down and bring the surfaces into close contact. At some places in the interface, metallic contact occurs but most parts of the surfaces are still covered by oxide and contaminants, which need to be dispersed by the ongoing plastic deformation of the surfaces. The close contact of the surfaces allows van der Waals forces to take effect. This is valid when identical or similar metals are being welded. If the metals are very different in hardness, the softer material deforms more than the harder metal. In that case there are more dislocations generated at the surface of the softer material. Therefore metallic bonding can take place by electron exchange between both surfaces.

In the second stage, metallic bonds are formed because of the increasing amount of atoms coming in contact at the surfaces. At a distance of 4 to 5 Å between the metal atoms, chemical bonds form between them and an exchange of electrons takes place between the surfaces. On the other hand, dislocation centers form because of the plastic deformation, which are the origin of the processes in the third stage. The metal combinations being welded mostly influence the duration of the second stage. When similar metals are welded the first stage proceeds directly to the third stage, because both surfaces deform simultaneously and active (dislocation) centers are formed immediately. If the metals are extremely different in hardness it takes longer to form active centers

on the surface of the harder material. For this to happen, the heat from internal and external friction is necessary to increase the ductility and allow eventually a phase change that will increase the deformability of the harder metal.

In the third stage that follows immediately after metallic bonding takes place in the weld region, interactions between the joint metals start in the weld region and in adjacent areas (sub layer). Plastic deformation has destroyed crystals and grains in the interface. Next to those plastically deformed regions, elastic deformed regions exist, causing residual stresses and areas with elevated energy. After a certain time, the residual stresses will relax, favored by the elevated temperatures and the altering superimposed stresses caused by the ultrasonic vibrations. The reasons for this relaxation process are atoms that change their functional locations in the crystal lattice structure. All the above takes place simultaneously; therefore, not only is relaxation taking place but also re-crystallization and diffusion. Diffusion processes have little effect on the formation of the joint, yet always result in strengthening the joint. Unfortunately there was no reason or explanation given for this phenomenon by Wodara. In metals, which have no solubility in each other in the solid state, the joint strength relies only on inter atomic interaction and is according to this not very strong.

Since USMW is a solid state bonding process it is imperative to have some degree of understanding of the processes that take place on a microscopic scale within the bonding area of an ultrasonic metal weld. Therefore this theory was introduced here briefly with no claim of completeness. It is also necessary to understand the source of residual stresses and their potential impact on weld strength after long periods of time.

2.2 Summary of the literature review

The mechanism of ultrasonic welding that emerges from this extensive body of prior work is that of a solid-state bond, caused by the relative motion-induced plastic deformation and fracture, dispersal of oxides and contaminants, thus allowing interatomic attraction to take effect. Even though there is some controversy about re-crystallization and diffusion in the weld zone, these events, if present, are the consequence of the heat generated at the weld interface by plastic deformation. It must be mentioned that experiments conducted to find the weld mechanism were done with a wide variety of 39 materials, equipment and weld parameters. Different methods of examination have also been used, which then lead eventually to different conclusions. When bonding wires, the metallic bond is made possible by external deformation rather than internal deformation. The temperatures generated in micro bonding are considerably less than those in sheet metal welding. Metal to glass and ceramic welds rely on diffusion to create an interface layer to which both material can adhere. In many cases of metal to glass/ceramic welds the glass is coated with a thin layer of metal prior to welding by conventional techniques.

Numerous researchers have measured the temperatures arising at the weld interface during USMW. The temperatures are dependent on the material used, as well as the welding parameters. In most cases the measured temperatures were 60 to 80 percent of the melting temperature of the metals. Theoretical approaches to temperature prediction are difficult because of insufficient knowledge of the material properties at elevated temperatures and the rather complex geometries of the parts and the adjoining sonotrode and anvil. These factors have made an analytical approach to the problem difficult, with no evidence of advanced simulation capabilities being applied to this area.

Over the years some advances have taken place in understanding the relationship between the input electrical impedance of the welder and the resulting forces and amplitudes at the tool tip in contact with the surface of the top part. Nevertheless, while helpful, these studies did not provide information on the critical interface forces. Manufacturers of ultrasonic welding systems have developed sophisticated power supplies with a great variety of control features. The electrical and acoustical power delivered to the sonotrode can be calculated and measured in different ways. But so far attempts to control the weld quality by these means have been not very successful.

In part, this difficulty arises because the effect of part dimensions and surface condition have not been included into the systems representation. All the researches, even though claiming to calculate or measure the power input into the weld, basically calculated or measured the power at the sonotrode, not at the weld interface.

Some understanding of the influence of part dimensions on the weld quality has emerged in terms of general phenomenological explanations, but in general this important area has received little attention in the ultrasonic welding community. So far only dimensions for which resonance could occur at the welding frequency have been considered. The influence of top part thickness has been found to be two fold, that of the decrease in vibration amplitude due to the elastic shear deformation across the thickness and the change of contact stress at the weld interface

The above briefly describes only a few aspects important for this work about USMW. For a more comprehensive overview over all aspects of USMW the reader is referred to Rozenberg [8] Rozenberg's book, even though from 1970, gives a very comprehensive review of the available literature up to that time. For a basic introduction to USMW, The American Welding Society handbook is most helpful.

CHAPTER -3

EXPERIMENTAL WORK

3. Experimental Details

3.1 Introduction

The specimens used in this process, ultrasonic welding are aluminium sheets. These sheets have dimension of 80 mm length, 20 mm width, and 0.56 mm thickness. Before ultrasonic welding of these sheets, those are cleaned with acetone as if any impurity will be found on sheets they can affect bond strength.

3.2 Machine Specification

3.2.1 TELSONIC ULTRASOINC MACHINE (used for USMW)

MAKE-TELESONIC

MODEL-M4000

POWER-3000W

FREQUENCY-20KHZ

NOMINAL PRESSURE-6 bar

Power System-Amplitude Regulated



Fig 3.1 TELSONIC ULTRASOINC MACHINE

3.2.2 INSTRON 1195 MACHINE

Machine parameters for test

Sample rate (pts/sec) - 4.552

Crosshead Speed (mm/min) -10.000

Full Scale Load (KN) - 20.000

Gauge Length- 57 mm



Fig 3.2 Instron 1195 Machine

3.3 TESTING PROCEDURE

The ultrasonic welding is carried out varying amplitude, weld pressure, weld time, and weld pressure with TELSONIC ULTRASOINC MACHINE. Amplitude was varied 80, 90,100 percentage of maximum amplitude of TELSONIC ULTRASOINC MACHINE, weld pressure was varied as 1.2, 1.4, 1.6 bar. Similarly weld time was varied as 0.2, 0.3, 0.4 sec

To decrease the no of test cycles and to simplmer the analysis the Taguchi orthogonal array method was used.

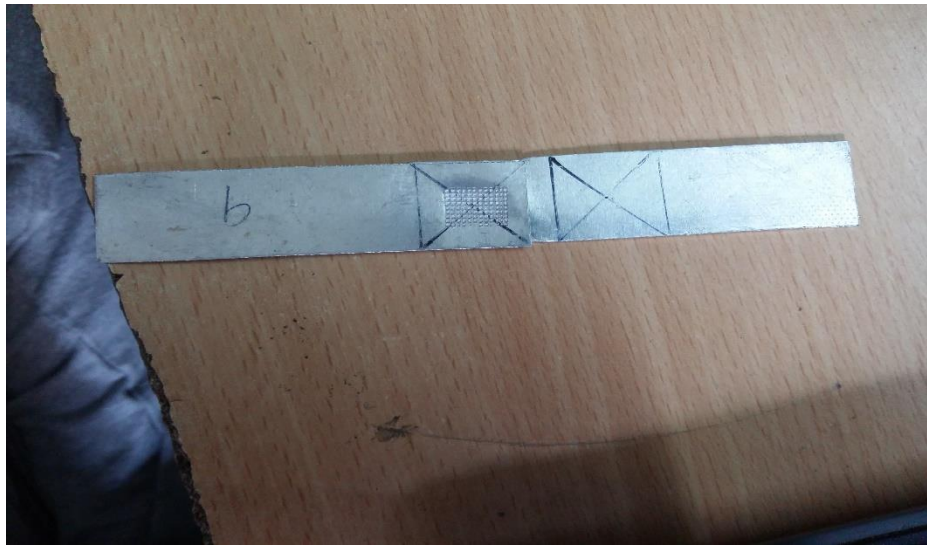


Fig 3.3 Ultrasonic welded Specimen

Tensile strength measurement was carried out with INSTRON 1195 machine and failure load is noted for each welded specimens.



Fig 3.4 Ultrasonic welded specimen after tensile test testing

CHAPTER-4
RESULTS, ANALYSIS AND DISCUSSION

4. RESULTS, ANALYSIS AND DISCUSSION

4.1 Results

Experiments were designed by the Taguchi method using an orthogonal array that was composed of three columns and 9 rows. This design was selected based on three welding parameters with three levels each. The selected welding parameters for this welding were: amplitude (% of max amplitude), weld pressure (bar), weld time (sec)

Table 4.1 Observation Table

Sample no	Amplitude (% of max)	Weld Pressure (bar)	Weld Time(sec)	Failure Load (KN)
1	80	1.2	.2	1.374
2	80	1.4	.3	1.343
3	80	1.6	.4	1.424
4	90	1.2	.3	1.364
5	90	1.4	.4	1.233
6	90	1.6	.2	1.374
7	100	1.2	.4	1.233
8	100	1.4	.2	1.243
9	100	1.6	.3	1.293

From the above table we can see for sample no 3 maximum failure load is observed that is 1.424 KN.

With sample no 3, the optimum parameters for welding were 80 (% of max amplitude), 1.6 bar weld pressure and 0.4 sec weld time.

To confirm the optimum parameter Main Effects Plots for Means were drawn.

4.2 Main Effects Plots for Means

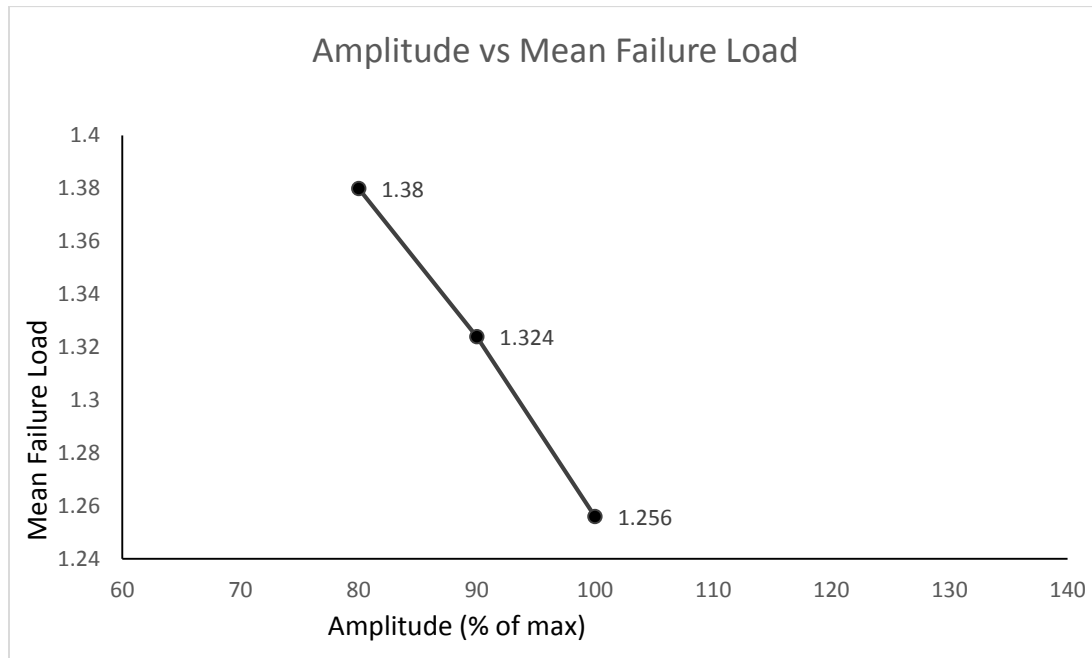


Fig 4.1 Variation of amplitude with Mean failure load

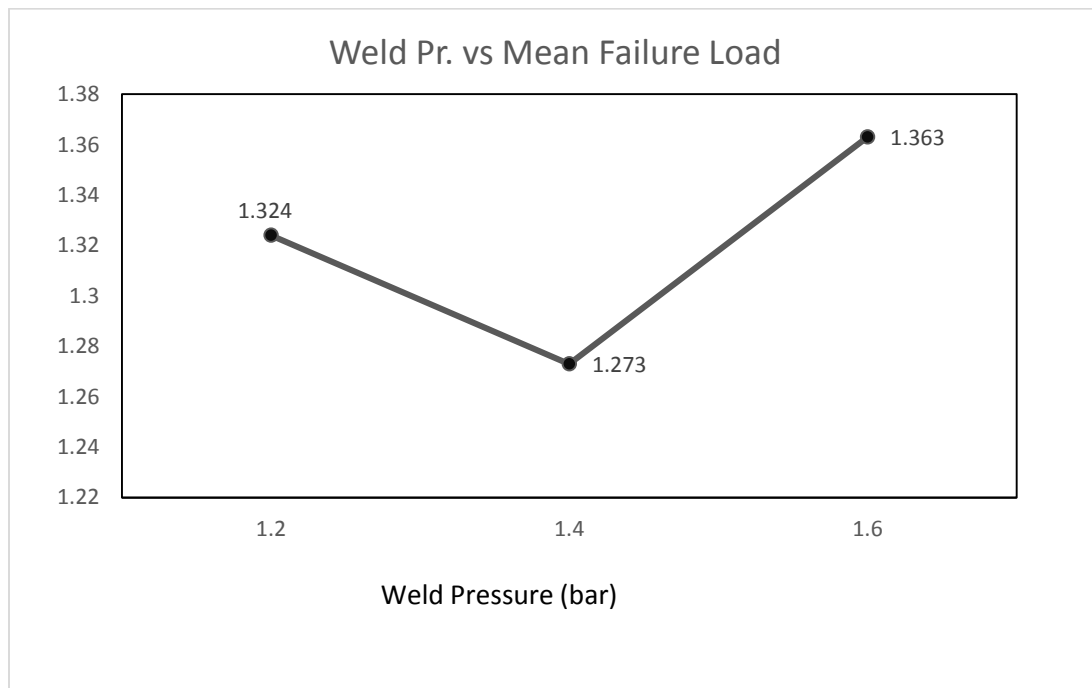


Fig 4.2 Variation of Weld Pressure with Mean failure load

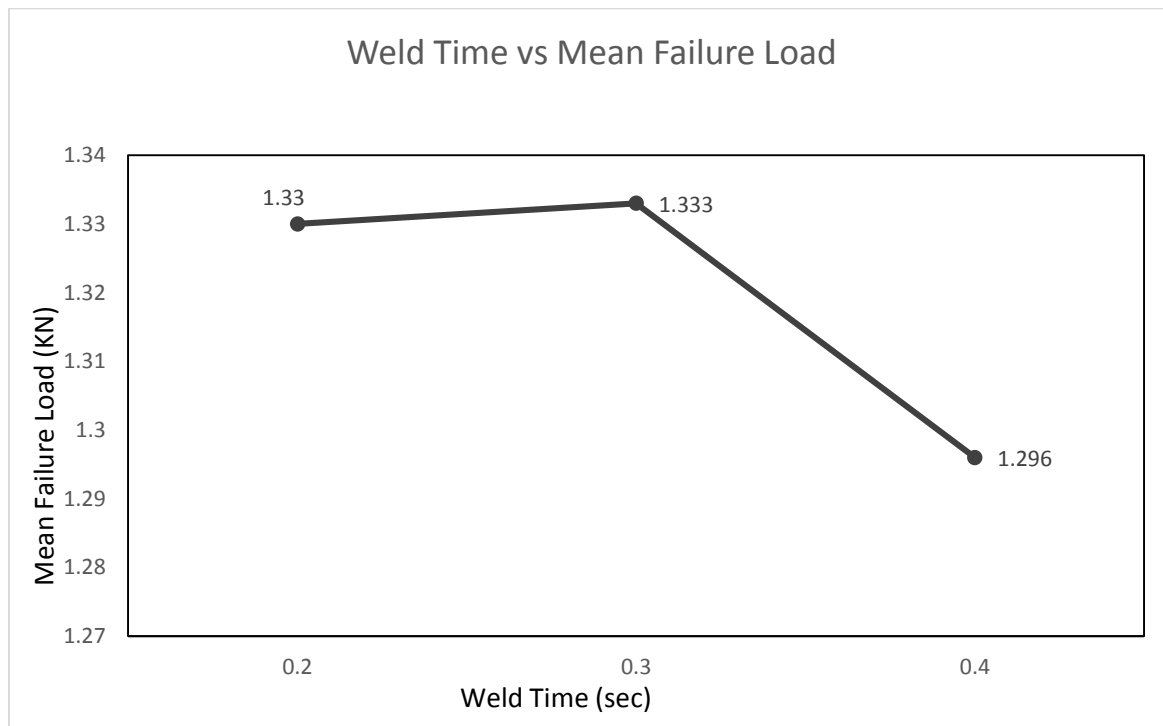


Fig 4.3 Variation of Weld time with Mean failure load

From the above 3 Main effects plots for means graph, it was found that at 80 (% of max amplitude), 1.6 bar weld pressure and 0.3 sec weld time there was maximum failure load, so this combination of parameters affects most to the failure load hence tensile strength.

So for conformation test, ultrasonic welding was carried out with the above parameters (80% of max amplitude, 1.6 bar weld pressure, 0.3 sec weld time). Failure load was 1.4371 KN with the above parameters and that was more than 1.424 KN from Table 4.1.

So the parameters (80% of max amplitude, 1.6 bar weld pressure, 0.3 sec weld time) are optimum for maximum failure load, hence higher tensile strength.

CHAPTER 5
CONCLUSION

5. CONCLUSION

This study is focused on joining of the metal sheets (aluminium & aluminium sheet) using ultrasonic welding technique. The variables are weld time, weld pressure, amplitude.

Main results obtained from the above study are-

- With increase in amplitude the failure load is decreasing or we can say that the weld strength or tensile strength is decreasing.
- At moderate weld pressure, failure load or tensile stress is minimum.
- At low or moderate weld time failure load is maximum hence maximum weld strength & tensile strength.

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